CLAIMS

1. A method of operating a fuel cell system, said method comprising:

configuring said system to include:

at least one fuel cell comprising an anode, a cathode and a membrane disposed between said anode and cathode;

an anode flowpath configured to couple said anode to a fuel source; and

a cathode flowpath configured to couple said cathode to an oxygen source, said cathode flowpath including a recirculation loop disposed therein;

decoupling said anode from said fuel source;

recycling fluid disposed in said cathode flowpath through said recirculation loop;

introducing fuel into said recirculation loop;

reacting said fuel with said recycled fluid until said recycled fluid becomes substantially oxygen-depleted; and

introducing said substantially oxygen-depleted fluid into said anode flowpath such that any fluid previously resident therein is substantially purged therefrom.

2. The method according to claim 1, wherein said step of configuring said system comprises the additional step of fluidly coupling a pressure source to at least one of said fuel source and said oxygen source.

3. The method according to claim 2, comprising the additional step of pressurizing fluid contained within said recirculation loop.

4. The method according to claim 1, wherein said recycling step further comprises closing a cathode exit valve disposed within said recirculation loop.

5. The method according to claim 4, wherein said recycling step further comprises opening a cathode flowpath recycle valve disposed within said recirculation loop.

6. The method according to claim 1, wherein said step of introducing said substantially oxygen-depleted gas into said anode flowpath comprises opening a purge valve that fluidly couples said cathode flowpath to said anode flowpath.

7. The method according to claim 6, wherein said purge valve is disposed between said cathode and a cathode exit valve.

8. The method according to claim 1, wherein said step of introducing fuel into said recirculation loop comprises adjusting a fuel inerting valve that fluidly couples said anode flowpath to said cathode flowpath.

9. The method according to claim 1, wherein said system defines at least a first operational state where said system is generating electricity, a second operational state where said system is not generating electricity, and a third operational state transiently between said first and second operational states.

10. The method according to claim 9, wherein said decoupling, recycling, reacting and both introducing steps comprise said third operational state.

11. The method according to claim 9, further comprising the step of filling said anode flowpath with fuel once said substantially oxygen-depleted fluid has substantially purged said anode flowpath.

12. The method according to claim 11, wherein said step of filling said anode flowpath with fuel once said substantially oxygen-depleted fluid has substantially purged said anode flowpath comprises fluidly isolating said anode flowpath from said cathode flowpath, and fluidly coupling said fuel source to said anode.

13. The method according to claim 12, wherein said step of fluidly isolating said anode flowpath from said cathode flowpath comprises closing a purge valve disposed therebetween.

14. The method according to claim 12, wherein said step of fluidly isolating said anode flowpath from said cathode flowpath further comprises closing a fuel inerting valve disposed therebetween.

15. The method according to claim 12, wherein said step of fluidly coupling said fuel source to said anode comprises opening a fuel supply valve disposed within said anode flowpath.

16. The method according to claim 11, comprising the additional step of placing said system in said first operational state.

17. The method according to claim 16, comprising the additional step of adjusting flow of said fuel until steady state operation is achieved.

18. The method according to claim 11, comprising the additional step of bleeding fluid from said oxygen source into said anode to assist said first operational state.

19. The method according to claim 18, wherein said bleeding step comprises opening a purge valve that fluidly couples said cathode flowpath to said anode flowpath.

20. The method according to claim 11, comprising the additional step of bleeding fuel from said fuel source into said cathode to assist said first operational state.

21. The method according to claim 20, wherein said step of bleeding fuel into said cathode comprises opening a fuel inerting valve that fluidly couples said anode flowpath and said cathode flowpath.

22. The method according to claim 1, comprising the additional step of regulating the amount of fuel being introduced into said cathode flowpath in order to maintain a substantially stoichiometric ratio between said fuel and said oxygen present in said recirculating fluid at least until said oxygen is substantially consumed in said reacting step.

23. The method according to claim 22, wherein said step of regulating the amount of fuel comprises:

sensing the amount of oxygen present in said recirculating fluid; and

adjusting a fuel inerting valve that fluidly couples said anode flowpath to said cathode flowpath by an amount necessary to maintain said substantially stoichiometric ratio.

24. The method according to claim 1, wherein said fuel is hydrogen-rich.

25. The method according to claim 24, wherein said fuel is selected from the group consisting of methanol, hydrogen, methane and gasoline.

26. The method according to claim 1, wherein said oxygen source comprises air.

27. The method according to claim 1, wherein said reacting step takes place in a combustor that is fluidly coupled to said cathode flowpath.

28. The method according to claim 27, comprising the additional step of cooling products produced during said reacting step.

29. The method according to claim 28, comprising the additional step of disposing a cooler between said combustor and said at least one fuel cell to effect said cooling step.

30. The method according to claim 1, wherein said reacting step takes place on a catalyst disposed on said cathode.

31. The method according to claim 1, wherein said step of introducing said substantially oxygen-depleted fluid into said anode flowpath comprises fluidly coupling said cathode flowpath downstream of said cathode with an inlet location in said anode.

32. The method according to claim 1, comprising the additional step of filling said anode flowpath with air once said previously resident fuel has been substantially purged therefrom.

33. The method according to claim 32, wherein said step of filling said anode flowpath with air is effected by closing a fuel inerting valve and opening a purge valve, each of said valves disposed between said anode flowpath and said cathode flowpath.

34. The method according to claim 1, wherein said step of decoupling said anode from said fuel source is accomplished by closing a fuel supply valve.

35. A method of preparing a fuel cell system for startup, said method comprising:

configuring said system to comprise:

at least one fuel cell comprising an anode, a cathode and a membrane disposed between said anode and cathode;

an anode flowpath configured to couple said anode to a fuel source;

a cathode flowpath configured to couple said cathode to an oxygen source, said cathode flowpath including a recirculation loop disposed therein; and

a plurality of valves configured to establish fluid communication between said anode flowpath and said cathode flowpath;

introducing fuel from said fuel source into said cathode flowpath;

recycling fluid disposed in said cathode flowpath through said recirculation loop;

introducing fuel into said recirculation loop;

reacting said fuel with said recycled fluid until said recycled fluid becomes substantially oxygen-depleted; and

introducing said substantially oxygen-depleted fluid into said anode flowpath such that any fluid previously resident therein is substantially purged therefrom.

36. The method according to claim 35, wherein said step of introducing said substantially oxygen-depleted fluid comprises opening a purge valve that fluidly couples said anode flowpath to said cathode flowpath, and subsequently opening a fuel supply valve that fluidly couples said fuel source to said anode.

37. The method according to claim 36, comprising the additional step of bleeding fluid from said oxygen source into said anode to facilitate low temperature starting.

38. The method according to claim 37, wherein said step of bleeding air into said anode comprises opening a purge valve disposed between said cathode flowpath and said anode flowpath.

39. The method according to claim 36, comprising the additional step of bleeding fuel from said fuel source into said cathode to facilitate low temperature starting.

40. The method according to claim 39, wherein said bleeding fuel step comprises opening a fuel inerting valve that fluidly couples said anode flowpath to said cathode flowpath.

41. A method of transiently operating a fuel cell system, said method comprising:

configuring said system to define at least a first operational state where said system is generating electricity and a second operational state where said system is not generating electricity, said system comprising:

at least one fuel cell comprising an anode, a cathode and a membrane disposed between said anode and cathode;

an anode flowpath configured to couple said anode to a fuel source;

a cathode flowpath configured to couple said cathode to an oxygen source, said cathode flowpath including a recirculation loop disposed therein;

at least one valve disposed within said recirculation loop to selectively allow recirculation of fluid therethrough;

a purge valve that fluidly couples said cathode flowpath to said anode flowpath;

a fuel inerting valve that fluidly couples said anode flowpath to said cathode flowpath; and

a pressure source coupled to said oxygen source;

placing said system in one of said first or second operational states;

decoupling said anode from said fuel source;

arranging said at least one valve disposed in said recirculation loop such that said fluid pressurized by said pressure source can be recycled therethrough;

arranging said fuel inerting valve such that fuel can be introduced from said fuel source into said cathode flowpath;

reacting said fuel with said recycled fluid until said recycled fluid becomes substantially oxygen-depleted; and

opening said purge valve such that said substantially oxygen-depleted fluid is introduced into said anode flowpath, thereby substantially purging said anode flowpath.

42. A device comprising:

at least one fuel cell comprising an anode, a cathode and a membrane disposed between said anode and cathode;

an anode flowpath configured to couple said anode to a fuel source;

a cathode flowpath configured to couple said cathode to an oxygen source, said cathode flowpath including a recirculation loop disposed therein; and

a plurality of valves configured to establish fluid communication between said anode flowpath and said cathode flowpath, said plurality of valves comprising:

- a fuel supply valve disposed between said fuel source and said anode;
- at least one valve disposed in said recirculation loop to selectively allow recycling of fluid therethrough;
- a fuel inerting valve disposed between said anode flowpath and said cathode flowpath to allow selective fluid communication therebetween; and
- a purge valve disposed between said anode flowpath and said cathode flowpath to allow selective fluid communication therebetween.

43. The device according to claim 42, further comprising a pressure source coupled to at least one of said fuel source and said oxygen source.

44. The device according to claim 43, wherein said at least one valve disposed in said recirculating loop comprises:

a cathode exit valve configured to selectively control back-pressure in an exhaust line in said cathode flowpath; and

a cathode flowpath recycle valve disposed between said oxygen source and said pressure source.

45. The device according to claim 43, wherein said pressure source comprises an air compressor.

46. The device according to claim 42, further comprising a combustor configured to promote reaction between fuel and oxygen.

47. The device according to claim 46, further comprising a cooler fluidly coupled downstream of said combustor.

48. The device according to claim 42, further comprising a catalyst disposed on said cathode.

49. The device according to claim 42, further comprising a controller configured to regulate the amount of fuel being introduced into said cathode flowpath.

50. The device according to claim 49, further comprising an oxygen sensor such that said controller is configured to manipulate said plurality of valves in response to a signal sent from said oxygen sensor.

51. A device according to claim 42, wherein said device further comprises a power conversion mechanism configured to take electricity generated by said fuel cell system and convert it to motive power.

52. A device according to claim 51, wherein said device further comprises a vehicle configured to house said fuel cell system and said power conversion mechanism, said vehicle movably responsive to said motive power generated in said power conversion mechanism.